OFFICES
McGuireWoods LLP
1750 TYSONS BOULEVARD, SUITE 1800
MCLEAN, VIRGINIA 22102

APPLICATION
FOR
UNITED STATES
LETTERS PATENT

Applicants: **Sang-Hyuck AHN and Sang-Jo LEE**
For: **METHOD FOR FABRICATING FIELD EMISSION DISPLAY WITH CARBON-BASED EMITTER**
Docket No.: **6161.0013.AA**

METHOD FOR FABRICATING A FIELD EMISSION DISPLAY WITH CARBON-BASED EMITTER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for fabricating a field emission display with a carbon-based emitter.

2. Description of the Related Art

A quality of a field emission display using a cold-cathode as an electron emission source depends on a characteristic of an emitter which is an electron emission layer.

Conventionally, such an emitter is formed in a tip-shaped spindt type made of Mo-based metal. Such a tip-shape spindt type emitter is disclosed in the U.S. Patent No. 3,789,471.

However, to fabricate a field emission display having such a tip-shaped emitter, a series of semiconductor manufacturing processes such as photolithography and etching processes for forming holes for fixing the emitter and a vapor deposition process for depositing Mo to form the metal tip. However, these processes are time-consuming and costly.

Accordingly, techniques for forming a planar emitter have been developed to simplify the manufacturing process while allowing the emitter to emit electrons under a relatively low voltage (10-50V) driving condition.

As a material for forming the planar emitter, well known is a carbon-based material such as graphite, diamond and carbon nanotube. Particularly, the carbon nanotube is expected as the most ideal material for the planar emitter as it effectively emits electrons under a relatively lower driving voltage.

An electric field emission display with such a carbon nanotube emitter is disclosed, for example, in the U.S. Patent Nos. 6,062,931 and 6,097,138.

In the patents, the carbon nanotube emitter is formed through a PCVD (Plasma Chemical Vapor Deposition) process, a coating process, a printing process and the like.

However, when the emitter is formed using the carbon-based material through a series of processes, the surface property of the planar emitter easily deteriorates, because the carbon-based material has a high bonding energy with other materials used in such processes.

For example, a photolithography process should be performed to form an electrode (gate and focusing electrodes) for emitting electric field on the emitter. A photoresist used for the photolithography process remains on the emitter surface, deteriorating the electric field emission characteristic. Etching solution used for patterning the electrode also deteriorates the emitter performance.

In addition, when the emitter is heat-treated for baking, the carbon contained in the emitter is burned as it reacts with oxygen (see FIG. 4).

As described above, when the emitter is formed of a carbon-based material, a variety of problems are encountered.

SUMMARY OF THE INVENTION

Therefore, the present invention has been made in an effort to solve the above problems.

It is an objective of the present invention to provide a method for fabricating a field emission display, which can prevent the electric field emission characteristic from being deteriorated by compensating for the surface damage of the emitter.

To achieve the above objective, the present invention provides a method for fabricating a field emission display, comprising the steps of forming a cathode electrode on a substrate; forming an emitter having a carbon-based material on the cathode electrode; depositing an emitter surface treatment agent on the substrate to cover the emitter; hardening the emitter surface treatment agent; and removing the hardened emitter surface treatment agent from the substrate such that the carbon-based material contained in the emitter can be exposed out of a surface of the emitter.

Preferably, the step of forming the emitter further comprises the steps of printing a paste having the carbon-based material on the cathode electrode; and heat-treating the printed paste at a temperate lower than a temperature for completely baking the paste. The step of printing the paste is performed through a screen-printing process using a metal mesh screen.

Preferably, the carbon-based material is selected from the group consisting of a carbon nanotube, graphite, and diamond.

Preferably, the step of depositing the emitter surface treatment agent is performed through a spin-coating process, and the step of hardening the emitter surface treatment agent is performed by a heat-treatment process.

Preferably, the emitter surface treatment agent is a polyimide solution.

Preferably, the step of heat-treating the printed paste is performed at the temperature of about 350-430°C for about 2 minutes.

The heat-treatment process is performed in a state where the substrate deposited with the surface treatment agent is located on a hot plate maintaining a temperature of about 90°C for about 20 minutes.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate an embodiment of the invention, and, together with the description, serve to explain the principles of the invention.

FIG. 1 is a sectional view of a field emission display that can be fabricated by a method according to the present invention.

FIGs. 2A, 2B, 2C and 2D are sectional views illustrating a method for fabricating an electric field emission display according to a preferred embodiment of the present invention.

FIG. 3 is a photograph showing a surface of an emitter fabricated under a method of the present invention.

FIG. 4 is a photograph showing a surface of an emitter fabricated under a conventional method.

FIG. 5 is a graph illustrating a relationship between a gate voltage and an anode current of a field emission display according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the present invention will be described in detail with reference to the accompanying drawings.

FIG. 1 shows a field emission display that can be fabricated by a method according to a preferred embodiment of the present invention.

A field emission display comprises front substrate 2 and rear substrate 4 that are disposed to define an inner space therebetween.

A cathode electrode 6 having plural line patterns is disposed on the rear substrate 4, and an insulating layer 8 is formed on the cathode electrode 6 to a certain height. The insulating layer 8 has a plurality of holes 8a that expose parts of the line patterns of the cathode electrode 6. A gate electrode 10 having a pluralilty of line patterns intersecting the line patterns of the cathode electrode 10 at right angles is formed on the insulating layer 8 except for a portion where the holes 8a are formed. The gate electrode 10 has holes 10a corresponding to the holes 8a. Emitters 12 are formed to a certain height on the exposed line patterns of the cathode electrode 6 through the holes 8a and 10a. The height of the emitter 12 is less than that of the insulating layer 8.

The emitters 12 are formed of a carbon-based material such as a carbon nanotube, graphite, diamond and the like and provided with a planar surface. In this embodiment, a plurality of carbon nanotubes are used as a material for forming the emitters 12.

Formed on the front substrate 2 is an anode electrode 14 having a plurality of line patterns, on which a phosphor layer 16 is formed.

The reference numeral 18 indicates spacers that maintain a predetermined cell

gap between the front substrate 2 and the rear substrate 4.

A feature of the invention is to provide a method for exactly aligning the nanotubes 12a on the surface of the emitter 12 when the emitter 12 is formed of the carbon-based material, thereby compensating for the damage of the emitter surface to prevent the electron emission characteristic from being deteriorated.

FIGs. 2A, 2B, 2C and 2D show steps of such a method for fabricating the field emission display.

First, the plural line patterns of the cathode electrode 6 are formed on the rear substrate 4 through a printing or sputtering process.

Next, the insulating layer 8 and the plural line patterns of the gate electrode 10 are formed on the cathode electrode 6. At this point, the holes 10a and 8a are also formed.

The insulating layer 8 is formed through a printing or CVD process, the gate electrode 10 is formed through a printing or sputtering process, and the holes 8a and 10a are formed through a photolithography process.

Next, the emitters 12 are formed on the plurality of line patterns of the cathode electrode 12. Preferably, the emitters 12 are formed through a screen-printing process using a metal mesh screen. That is, a mesh screen formed of a stainless wire and paste for the emitters are first prepared. Preferably, the paste is composed of carbon nanotube powder, binder, vehicle that is dissolved in a liquid state at a high temperature and solidified by a baking process, and a solvent. Further preferably, as the binder, vehicle and the solvent, used are respectively ethyl cellulose, glass powder and terpineol.

After the paste is printed on the cathode electrode 6 through the mesh screen, it is baked to harden the printed paste, thereby forming the emitters 12.

Preferably, the baking process is performed at a temperature lower than the actual baking temperature of the paste such that less than 50% of the vehicle is solidified. In this embodiment, the baking process is performed at a temperature of 350-430 °C for 2 minutes. For the reference, the actual baking process for completely hardening the paste is performed at a temperature of about 500-600 °C for 10 minutes.

After the emitters 12 are formed through the above-described process as shown in FIG. 2a, a process for treating the surface of the emitters 12 is performed. That is, after printing the paste on the cathode electrode, the surfaces of the emitters 12 may be damaged during the following process such as the baking process such that the carbon nanotubes 12a are not vertically arranged. Therefore, the surface treatment process is performed to compensate for the damage of the surfaces of the emitters 12.

In the surface treatment process, surface treatment agent is deposited on the rear substrate 6 to cover the emitters 12 through, for example, a spin-coating process. The deposited surface treatment agent is hardened through a heat-treatment process to form a treatment film 20 as shown in FIG. 2b.

Preferably, as the surface treatment agent, polyimide solution made by dissolving polyimide in N-methyl-2pyrrolidone solvent.

The heat-treatment process for hardening the surface treatment agent is performed in a state where the rear substrate 6 deposited with the surface treatment agent is located on a hot plate maintaining a temperature of about 90 °C for 20 minutes.

Next, the hardened surface treatment agent (treatment film) 20 is removed from

the rear substrate 6 and the surfaces of the emitters 12 are activated. That is, a process for exposing the carbon nanotubes 12a out of the surfaces of the emitters 12 is performed.

Namely, when the treatment film 20 is detached from the rear substrate 4 by using physical force as shown in FIG. 2c, part of the surfaces of the emitters 12 are removed together with the treatment film 20 to define new surfaces of the emitters 12. As a result, front ends of the carbon nanotubes 12a are exposed out of the new surfaces of the emitters 20 as shown in FIG. 2d.

FIG. 3 shows a photograph of an emitter 12 which has gone through the surface treatment process as described above. As shown in the photograph, the front ends of the carbon nanotubes 12a are definitely exposed out of the surface of the emitter 12 when compared with a conventional emitter shown in FIG. 4.

FIG. 5 shows a graph illustrating a relationship between a gate voltage V_G and an anode current (I_A) of a field emission display made under the method of the present invention.

As shown in the graph, in the inventive field emission display, a gate voltage of about 100V is required to obtain 40 μA, while in the conventional field emission display, a gate voltage of about 300V is required to obtain 40 μA. This shows that the field emission display made under the present invention can be driven under a relatively low voltage.

While this invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is

intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.